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ABSTRACT

This study investigated the effectiveness of using the Calcumate, a copyrighted commercially available product, in teaching subtraction to average, disturbed, and retarded children in third, fourth, and fifth grades. The mechanical device simulates borrowing in subtraction problems involving two-digit numbers. Forty students were given these devices for introductory work with subtraction; they were told to use the aids only as long as they needed them. The instructional phase lasted 30 days, with students performing subtraction problems each day. Third-grade students were given 20 problems to perform in 30 minutes; other subjects were given 10 problems and 15 minutes. In all groups, substantial gains in ability to subtract with borrowing were recorded. Eighty-five days after the special instruction ended, students were retested on subtraction without using their Calcumates, and achievement continued to be high. (SD)

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CALCUMATE PART I: EFFECTS OF USING A MECHANICAL DEVICE TO TEACH SUBTRACTION WITH BORROWING TO SCHOOL CHILDREN

(Abbreviated Manuscript)

by

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ABSTRACT

This study investigated the effects of using a mechanical device to assist pupils in learning to subtract where two-digit borrowing (regrouping) was required. The device and associated work was concerned with the effects of antecedent events upon this subtraction behavior. Experimentation was carried out across third, fourth, and fifth graders and children labeled disturbed and/or retarded who had experienced little or no success in this arithmetic process in their regular classrooms and an outside room. The results confirmed the effectiveness of the device in teaching this process and suggest several possible areas for future research and application.

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FOOTNOTE

[1]The Calcumate (pronounced, Kal-q-mat) is a registered name and a copyrighted product. The Calcumate is available through H and H Enterprises at a cost of $3.50 each with a 20% discount on orders of 10 or more. Correspondence, additional information, or ordering should be directed to H and H Enterprises, Inc., Box 3342, Lawrence, Kansas 66044.

Most applied behavior analysis research conducted in public school settings has focused primarily on social behaviors (Schwarz and Hawkins, 1970; Reynolds and Risley, 1968; and Cossairt, Hall and Hopkins, 1973). Generally, manipulation of consequences has been a primary experimental v riable introduced to effect behavior change (Copeland, Brown, Axelrod and Hall, 1972 and Hillman, 1969). Recently, investigations of academic behaviors have increased (Harris and Sherman, 1973; and Lahey and Drabman, 1974).

The purpose of the present study was to assess a device, Calcumate, that teaches the skill of 2-digit subtraction with borrowing (regrouping) by manipulating antecedent stimuli. This study is similar to that by Lovitt and Curtiss (1968) in that no effort was made to alter the consequences of the behavior.

METHOD

Subjects and Setting:

A total of 18 third graders, 7 special education (ED/LD) students age 8-10 and 15 fourth and fifth graders from a Kansas City inner-city school served as subjects. The third graders and special education students received treatment in their classrooms while the fourth and fifth graders were treated in a 12' X 12' room adjoining the school's library. The third grade population represented students who had received traditional borrowing instruction 4 months prior to the study. Originally, the third grade teacher had referred 24 3rd grade pupils for the study but during the baseline phase it was found that 6 of the pupils had acquired the borrowing

skill and they were dropped as subjects. The fourth and fifth graders were identified by their teachers as being deficient in the skill after receiving conventional instruction in the 2nd and 3rd grades. The special education students had received only incidental instruction in borrowing.

Procedure

Daily worksheets of 20 two-digit subtraction problems selected from a 250 problem pool, were presented throughout the experiment. Problems, though randomly selected, were restricted in that; 1) no problem could be used more than four times throughout the study and 2) no particular problem could appear twice on the same day's worksheet nor again on the following day's worksheet.

The Experimenter daily passed out the worksheets to each student group (see notation), instructed them to compute the problems and collected them at the end of 30 min. The E graded each paper recording the number of correct answers on the paper and had the students' teacher return them to the pupils on the following day.

Reliability (computed by, $R=\frac{\text{Agreement}}{\text{Agreement + Disagreement}} \times 100$) was taken 15 times for the third grade population yeilding a 99.6% mean agreement; 10 times with the special education students with a mean agreement of 100% and 12 times with the fourth and fifth graders yeilding a mean agreement of 99.9%.

The third grade students received 20 problem worksheets daily with a completion time limit of 30 min. The special education students and the fourth and fifth graders received 10 problem worksheets and had 15 min in which to complete them. This change was instituted because of the extremely

notation There were three separate experiments conducted. However, they are combined in this report as the procedures and instructions were essentially the same.

low operant levels did not necessitate 20 problems (0/10 and 0/20 are still 0).

Students were told by the E.; "Complete the subtraction problems as best you can. You have 30 (or 15) min to finish the work. If you finish before the 30 (or 15) min are up, turn your paper over and complete your other school work or begin the assignment on the board. I will collect the papers at the end of 30 (or 15) min. You may begin." No academic instruction related to the worksheet was given in any part of the experiment. No attempt was made to alter a particular teacher's routine teaching procedures in any part of the experiment. At no time did the E. ask a teacher to do more than return corrected papers.

Calcumate phase

As the students were randomly selected for treatment the E. accompanied them to a hallway where they received instructions in using the Calcumate. (See Fig. 1 for these instructions and their relationship to Calcumate). Students were told before each 30 (or 15) min session to use the Calcumate only as long as they needed it.

Post Calcumate (baseline$_2$ phase).

This condition was identical to baseline$_1$ in that Calcumates were removed while all other instructions and equipment remained the same. Students returned to this condition when they were observed completing their worksheet without using the Calcumate for two consecutive days[1].

Post Check

This phase represented a delayed check (86 days) of the subtraction with borrowing skill to assess maintenance for the third graders.

[1]Graph designations of F(Fade) indicate that the student was observed by the E. not using Calcumate to solve the problems while O(OFF) indicates that the student was no longer given a Calcumate.

RESULTS

Figure 2 presents the results of the experiment (20 problem worksheets) for all 8 treatment groups of third graders. The mean baseline rates for all groups was 1.87 answers correct (range of means, 0.23-3.66). The mean correct rate for Calcumate phase was 13.5 answers correct (mean range 11.69 - 17.20). The Post Calcumate (noted as 0-off) rates of the 11 subjects who no longer required the device was 17.14 (a 5.24 increase over the 11.9 rate of these same pupils during the Calcumate phase. Furthermore, this figure represents a 15.26 increase in the correct rate over their mean baseline rate of 1.88. Figure 3 presents the individual records of three of the subjects who were typical of the 18 third grade students.

Figure 4 presents the results of the experiment (10 problem worksheets) for the special education students. The mean baseline rate was 0.24 answers correct (range 0.00 - 0.50). The mean rate increased during the Calcumate Phase to 7.92 answers correct (range, 5.67 - 8.73). With four pupils, Herman, Floyd, Greg and Jennie, a one day reversal was used to assess whether students who had not voluntarily discontinued using the Calcumate would be able to borrow accurately without the device. A short reversal was also implemented with Jennie, Eddie and Elbert for similar reasons.

Figures 5 and 6 present the results of the experiment carried out with the 15 fourth and fifth graders whose problem worksheets contained 10 problems. The mean baseline rate for all subjects was .62 answers correct (range 0.0 - 3.5). The mean Calcumate Phase rate increased to 8.86 answers correct (range 6.64 - 9.85). Twelve pupils went into a Post Calcumate Phase (noted as 0 - off). Their mean baseline rate was 0.64,

their mean Calcumate Phase rate was 8.68 and their mean Post Calcumate rate increased to 9.16 answers correct.

DISCUSSION

The results of these experiments indicate that the Calcumate is a useful device for assisting pupils in learning to borrow in two-digit subtraction. While using the Calcumate every pupil computed subtraction problems requiring borrowing at well above baseline rates. Furthermore, those who went off the Calcumate (Post Calcumate Phase) maintained or increased their correct answer rates when they were no longer dependent on it.

The multiple-baseline research design indicated that the introduction of the Calcumate was functional in increasing subtraction scores. While it is true that 6 third grade pupils began working the problems correctly during the baseline phase of the study and were dropped from the experiment, the remaining 18 all began borrowing correctly only after being introduced to the Calcumate. While the increase in scores of a few of these pupils might have occurred with time, it is highly improbable that the scores of each of the eight randomly selected treatment groups of pupils would have occurred almost immediately after the experimental procedure was introduced and not before. The fact that similar effects were systematically produced with other subjects lends further support to the functional relationship between using the Calcumate and the increase in correct problem solving.

Since one of the goals in teaching computation skills is to have pupils do so independently of mechanical devices or other aids, it is encouraging that a number of pupils faded off the Calcumate completely. During this Post Calcumate ($baseline_2$ phase) they maintained their higher performance levels.

Initially, the Experimenter did not program a designated Post Calcumate Phase in his study. Therefore, only those pupils who went "off" the Calcumate should be considered members of the Post Calcumate Phase. Figure 2 illustrates individual performance and typifies Post Calcumate Phases that can be designated for any student who went "off" the device.

It can be hypothesized that the initial function of the Calcumate was to give these pupils a step by step "fool proof" procedure for carrying out borrowing (regrouping) in the subtraction process, a process they had not learned from conventional teaching procedures. In other words, it would seem that the Calcumate provided better discriminative stimuli (S^D's) to the student than those provided by usual teaching procedures. Perhaps after going through the simple Calcumate procedures (responding to the S^D's) the same way time after time, the steps in the borrowing chain became clear to them and they were able to begin carrying them out without the device. Evidently, once the process became clear to them it was more reinforcing to compute without the Calcumate, for pupil after pupil discontinued using it. It is uncertain if this was due to the fact that it now took less time to do the problems without the Calcumate or whether it was intrinsically reinforcing to be independent of the device. Perhaps both or even additional factors were operating.

Apparently, subtraction with borrowing is usually a difficult and complex skill to master. The Shawnee Mission Unified School District, Shawnee Mission, Kansas, has annually surveyed 26,000 K-6 children from 1972 to the present in the area of arithmetic (Muller, 1974). It was found in both years that children have the most difficulty with subtraction and borrowing and also have the greatest dislike for this process.

Furthermore, although maintenance of the borrowing skill was deficient for some third grade students, their deterioration patterns traditional instruction deterioration as compiled in the Muller (1974) survey. It does appear, however, that deterioration of the borrowing skill might be a function of the baseline lengths (which shortened the Calcumate Phase) as well as the delay between the end of the Calcumate Phase and the beginning of the Post Check (86 days). These considerations are under investigation.

Another point well worth mentioning is the fact that large populations can be taught by the Calcumate with relative ease. Applied research has often concerned itself with interventions aimed at only one or two subjects. Efforts must be made to find workable materials and procedures that are effective for entire classrooms.

The Calcumate would seem to be a device which holds promise as an aid in teaching the complex process of borrowing in subtraction. Research now being conducted indicates that results similar to those obtained by the Experimenter can be achieved by regular classroom teachers using the device. In one second grade classroom, children who used the Calcumate invariably learned the borrowing process much more quickly than those who received modern math instruction only. (Robie, Copeland and Hall, in prep).

Presently, Calcumate research is being conducted in suburban area schools by the Experimenter and classroom teachers, as well as, by teachers acting independent of the Experimenter.

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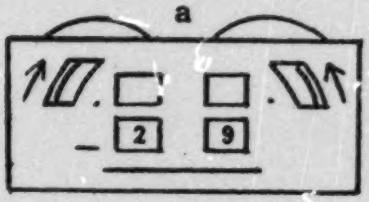
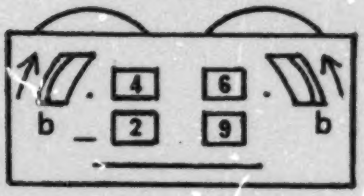
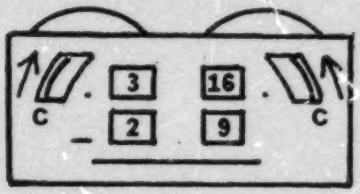


a " With your Calcumate (in subject's hands), locate the bottom number (subtrahend - 29) of the problem with the top wheels."



b " Make the top number (minuend - 46) of the problem by moving the side wheels with your thumbs in the direction of the arrow."



c " Using your thumbs, move each top number of the problem one number in the direction of the arrow on either side of these wheels."

d " Subtract. Subtract only from the Calcumate."

e " Write your answer on the worksheet."

Calcumate (4"x10") - Face Plate Removed

note; Tens digits are blue, units are red, dotted arrows for reference only.

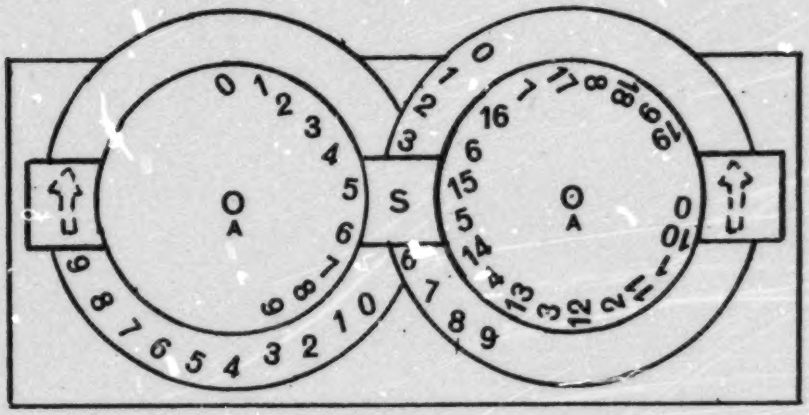


Fig. 1. Operational diagram of Calcumate with sequenced instructions (a - e) given to students: with example; 46
- 29
—

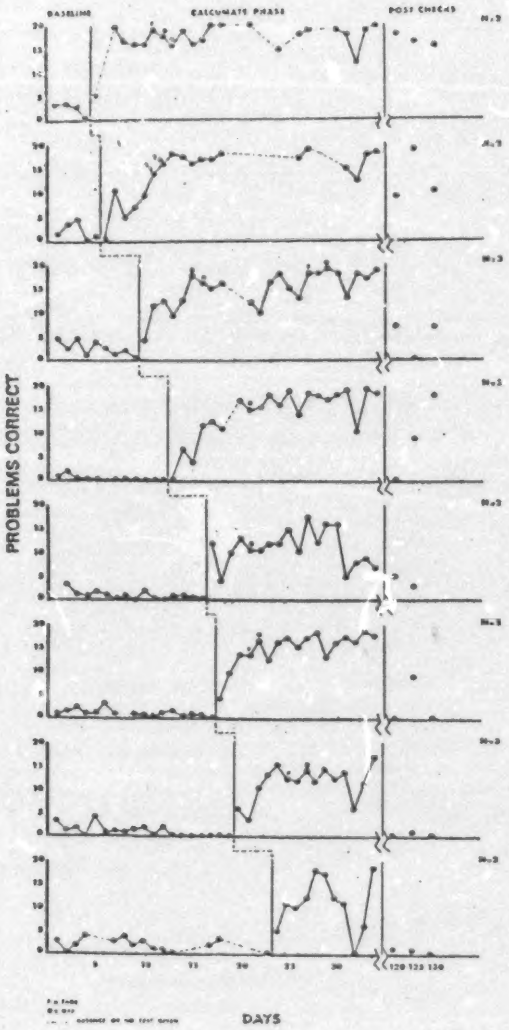


Fig. 2 A record of the number of problems correct on a 20 problem worksheet requiring two-digit borrowing with a 30 minute time limit. In this experiment, 18 of 30 students in the third grade classroom who used the Calcumate are presented in 8 groups with an "N" denoting the number of subjects in each group. The data points for each group represent the mean number of problems correct. Baseline - no Calcumate. Calcumate Phase - Calcumate used while solving problems. Post Checks - identical to Baseline condition; one check per 5 day interval.

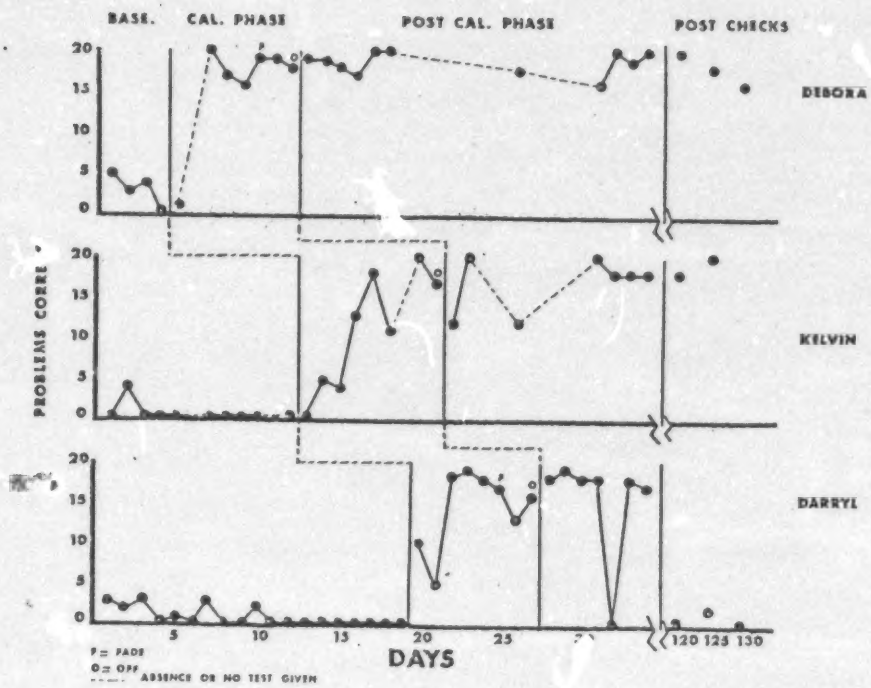


Fig. 3 A record of the number of problems correct on a 20 problem worksheet requiring two-digit borrowing with a 30 minute time limit. In this experiment, a representative sample of 3 of the 18 students in the third grade classroom of 30 who used the Calcumate are presented. Data points represent the number of problems correct. Baseline - no Calcumate. Calcumate Phase - Calcumate used while solving problems. Post Calcumate Phase - student no longer using the Calcumate; identical to Baseline. Post Checks - identical to Baseline conditions; one check per 5 day interval.

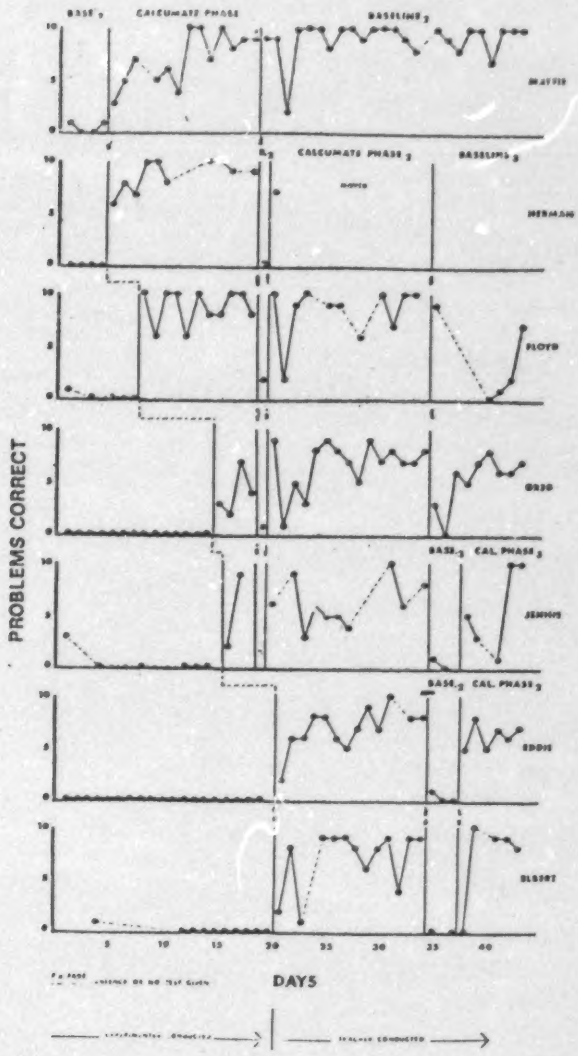


Fig. 4 A record of the number of problems correct on a 10 problem worksheet requiring two-digit borrowing with a 15 minute time limit. In this experimen. 7 special education students who used the Calcumate are presented. The data points represent the number of problems correct. Baseline - no Calcumate. Calcumate Phase - Calcumate used while solving problems. Baseline $_2$ reinstatement of Baseline$_1$. Calcumate Phase$_2$ - reinstatement of Calcumate Phase$_1$. Baseline$_3$ - reinstatement of Baseline$_1$. Calcumate Phase$_3$ - reinstatement of Calcumate Phase$_1$.

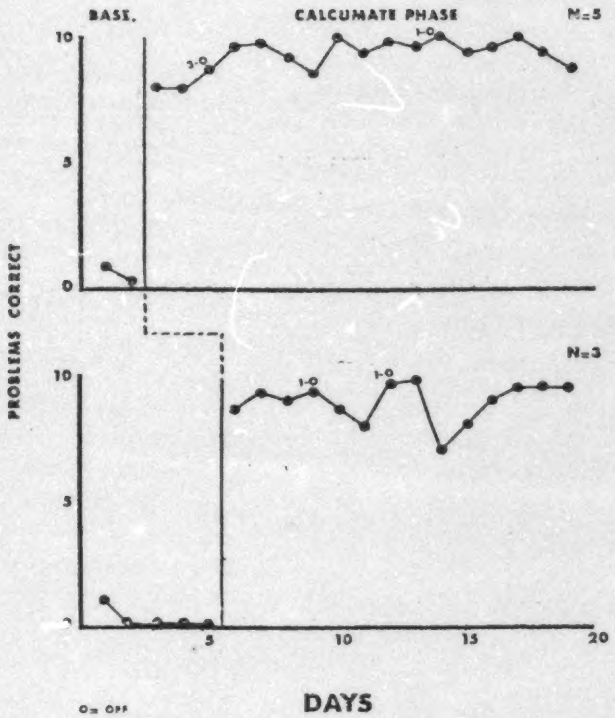


Fig. 5 A record of the number of problems correct on a 10 problem worksheet requiring two-digit borrowing with a 15 minute time limit. In this experiment, 8 fourth and fifth grade students who used the Calcumate are presented in 2 groups with an "N" denoting the number of subjects in each group. The data points for each group represent the mean number of problems correct. Baseline - no Calcumate. Calcumate Phase - used while solving problems. Six of the 8 students went "off" the Calcumate and are included with the 2 students who did not throughout the Calcumate Phase. (see "o" designations)

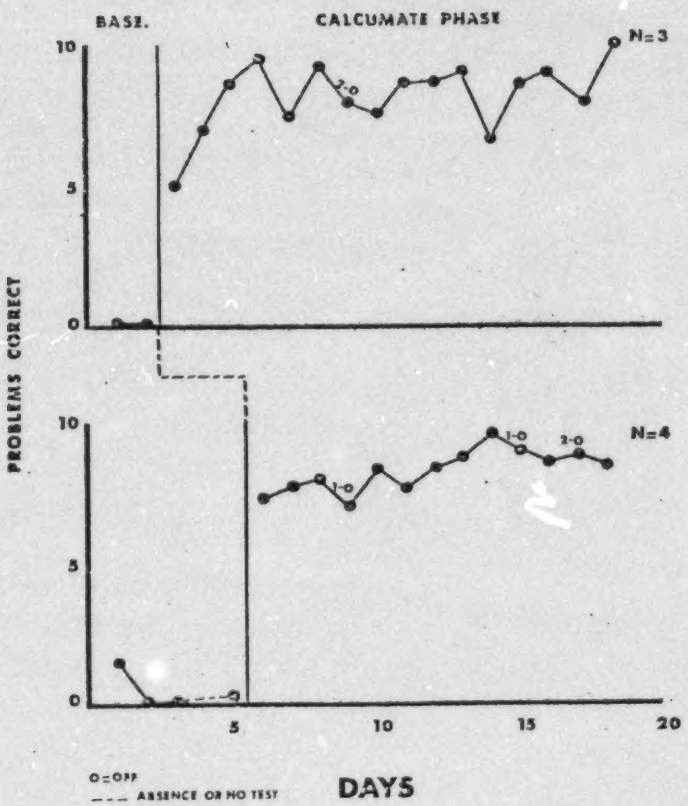


Fig. 6 A record of the number of problems correct on a 10 problem worksheet requiring two-digit borrowing with a 15 minute time limit. In this experiment, 7 fourth and fifth grade students who used the Calcumate are presented in 2 groups with an "N" denoting the number of subjects in each group. The data points for each group represent the mean number of problems correct. Baseline - no Calcumate. Calcumate Phase - Calcumate used while solving problems. Six of the 7 students went "off" the Calcumate and are included with the one student who did not throughout the Calcumate Phase (see "o" designations)